EFFECTS OF EXOGENOUSLY APPLIED INDOLE-3-ACETIC ACID (IAA) TO COTTON

A Dissertation

by

JENNY DALE CLEMENT

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2010

Major Subject: Agronomy

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Approved by:

Chair of Committee,	Steve S. Hague
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ABSTRACT

Effects of Exogenously Applied Indole-3-Acetic Acid (IAA) to Cotton.

(May 2010)

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Chair of Advisory Committee: Dr. Steve S. Hague

There is a need in the cotton industry for cultivars with enhanced lint yield potential and high-quality fiber properties. Indole-3-acetic acid (IAA) is a phytohormone that is predominantly responsible for cell elongation and required for primary elongation in cotton fiber development. An increase in IAA at specific fiber developmental stages may promote increased lint percent and longer fibers. Objectives of this research project were to determine how exogenous applications in a field environment affect fiber traits and lint yield potential in diverse genotypes. The first study examined application methods to ascertain the optimal placement and timing of IAA. The second study focused on genotype reactions to elevated levels of IAA. Results indicate exogenously applied IAA provided a potential yield increase but did not improve fiber length. Further research needs to be conducted to effectively understand IAA's role in fiber development and establishing protocols for maximizing IAA potential in a field environment.

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DEDICATION

To the road less traveled.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Steve Hague, for taking a chance and having patience during all the tears. Thanks to my committee members, Dr. Smith, Dr. Cothren, and Dr. Gould, for their guidance and support throughout the course of this research.

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Thanks to my parents and my Nana for their encouragement and financial assistance. Thanks to my sisters: Emily for counting 1,000s of seeds, Sara for taking boll samples, Catherine for organizing and finding missing samples, and to Julie for financial encouragement. Finally, I thank B, for giving me the support I needed to finish strong.

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NOMENCLATURE

Abscisic Acid	ABA
Gibberellins	GA_3
IAA	Indole-3-Acetic Acid
Phytogen 355	PSC 355

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CHAPTER I

INTRODUCTION

Cotton is an important economic crop in the USA. Increasing crop yield potential has been a major goal in cotton research for decades. More recently in the US, there has been urgency among cotton researchers to improve fiber quality. This mission was in large part prompted by new textile processing equipment that required longer, stronger and more uniform fibers to operate at optimal efficiency rates. Even more recently, the domestic textile industry, which traditionally consumed most of the US produced mid-grade cotton, has dramatically declined. As a result, US cotton growers must now market their cotton in an international arena with higher fiber quality standards than what was traditionally expected.

Understanding the biological properties of cotton fiber is critical to developing and improving fiber quality. Cotton fibers are elongated epidermal cells initiated on seed ovules. Development consists of four phases of growth: initiation, primary elongation, secondary wall formation and maturation. These stages are influenced by environmental, genetic, physiological and biochemical factors.

The composition of the fiber greatly contributes to the overall final product which determines its economic value. Fiber length affects spinning performance and

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This dissertation follows the style of Agronomy Journal.

determines yarn size. Fiber strength and micronaire, an indication of fiber fineness and relative maturity, contribute to the estimation of yarn strength and spinnability (May, 1999). Fiber properties are not independent but rather interrelated based on developmental processes, length and rate of each phases and genetic background.

One possible area of improving fiber quality could be supplemental use of hormone application. Phytohormones play a significant role in plant development and have been investigated extensively. Indole-3-acetic acid (IAA) is a phytohormone that is predominantly responsible for cell elongation and required for primary elongation in cotton fiber development (Birnbaum et al., 1974).

Investigatory tissue culture experiments confirmed previous findings on IAA's relationship with fiber development. Cotton ovules from Phytogen 355 and Pima SJ-7 were excised at 2 and 4 days past anthesis and placed on nutrient supplemented media. Media was prepared using the protocol of Beasley and Ting (1973). IAA hormone was made by preparing a stock solution of 1mg/L. Various rates were tested until final concentrations were established at 0.25mg/Land 0.5mg/L for *G. hirsutum* and 0.1mg/L and 0.3mg/L for *G. barbadense*. The hormone was filter-sterilized and placed into appropriate flasks prior to ovule placement. The flasks were kept in constant darkness for a two week period. Treatments consisted of 4-5 flasks with one ovary, approximately 25-30 ovules, per flask. Due to contamination the final treatment number varied from 2-3. At the end of two weeks, ovules were compared and digital images were recorded. Figures 1 and 2 show results of increased IAA.

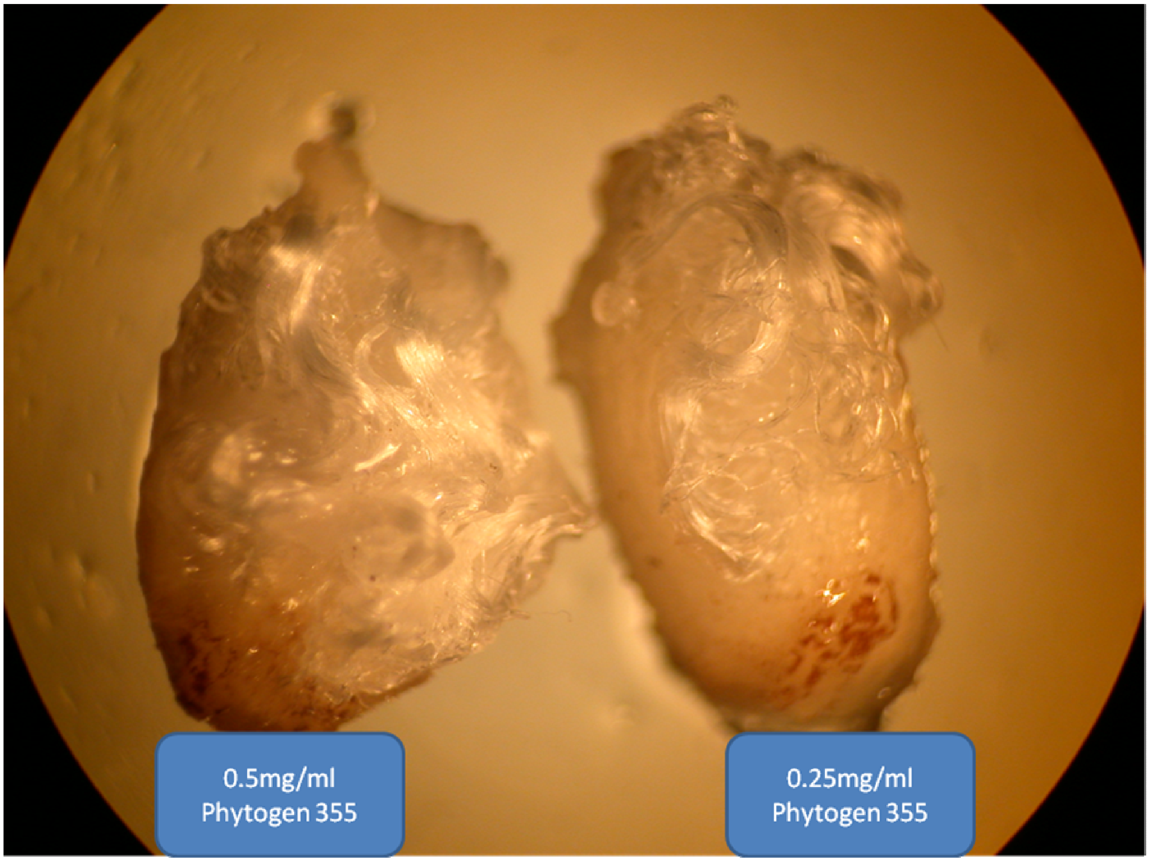

Figure 1. Phytogen 355 ovules at 16 dpa on IAA suplemented media.

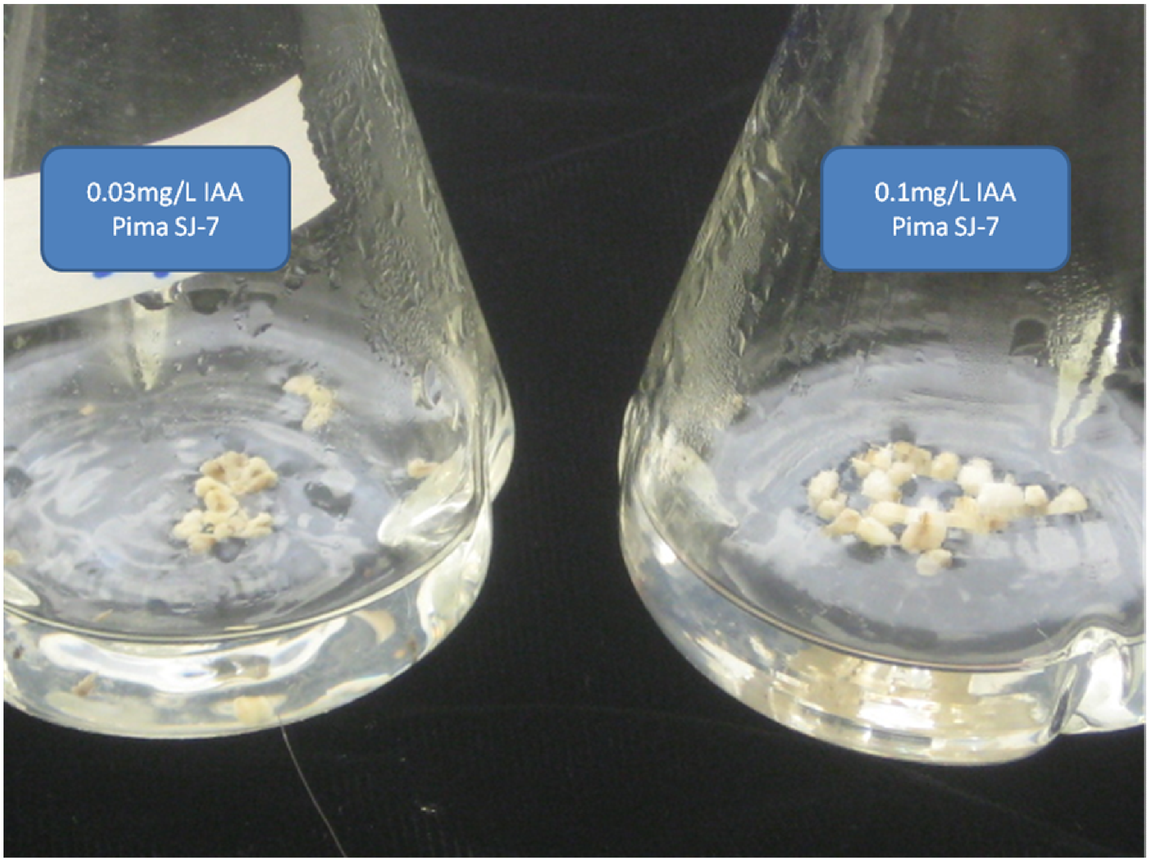

Figure 2. Pima SJ-7 ovules at 18dpa on IAA supplemented media.

Fiber development has been extensively studied in tissue culture. However fiber development continues after the nutrient media is exhausted. Therefore few studies have been conducted in a field environment concerning IAA and its impact on early fiber developmental stages.

Objectives

Objectives of this research are:

1. Characterize effects of exogenously applied IAA on cotton fiber properties and yield components in a field environment.
2. Determine how genotypes react to exogenous IAA applications and application methods.

CHAPTER II

LITERATURE REVIEW

Growth during the phase of primary elongation determines fiber length. Extended periods of primary elongation tend to result in longer fiber length (Applequist, 2001). Fiber strength and micronaire are related strongly to the degree of cellulose deposition during secondary wall formation (Hsieh, 1999).

Initiation begins one day prior to anthesis in both fertilized and unfertilized ovules; however, fertilization is necessary for fiber elongation to begin (Van't Hof , 1998; Gialvalis and Seagull, 2001). Only one out of four epidermal cells per ovule differentiate into fibers (Stewart, 1975; Applequist, 2001) with an approximate total of 14,500 fibers per ovule (Van't Hof, 1998). Fibers seed^{-1} is an important yield component. Increasing total number of initials that subsequently elongate into mature fibers may contribute to increases in total yield boll^{-1} and acre^{-1}.

Primary elongation is the lateral expansion of the fiber cell and related to fiber length. Primary elongation begins immediately after anthesis and is dependent on fertilization, reaching its maximum rate around 10 days post anthesis (dpa) and can continue up to 45 dpa in long staple cotton (Naithani et al., 1982) or cease around 25 dpa in shorter staples (Jasdanwala et al., 1977). Differences in rates and duration of fiber cell elongation show a direct correlation to final fiber length. Differences in the length of primary elongation periods are due to genetic variation between cotton species and within cultivars (Berlin, 1986).

During secondary wall formation, cotton fibers increase in dry mass due to an increase in cellulose deposition. Secondary wall formation begins as early as 18 dpa to 25 dpa (Thaker et al., 1986; Jasdanwala et al. 1977) and continues until the boll opens sutures. Rate of cellulose deposition is directly related to fiber strength (Wang, 2009) and amount of cellulose partially determines yield (Haigler, 2007). The amount of cellulose deposited within a given fiber cell considerably varies among Upland cotton genotypes. Moharir et al. (2003) reported interspecific variability as well. The amount of cellulose synthesized and deposited within a fiber was significantly different between *G. hirsutum* and *G. arboreum* cotton plants.

The transition between primary elongation and secondary wall formation was once thought to be mutually exclusive, but evidence by Schubert et al.(1973) and confirmed by Jasdanwala et al. (1977) showed a period of overlap between phases. This overlap aids in understanding the strong link between fiber length and strength. The transition of energy priorities in the boll from fiber elongation to cellulose deposition causes physiological competition for resources directly affecting fiber properties. Transition could be regulated by the phytohormone auxin in the form of indole-3-acetic acid (IAA) (Jasdanwala et al., 1977).

Phytohormones are essential for plant growth and development. They play a critical role in numerous physiological and biochemical processes. Cytokinins, and abscisic acid (ABA) are major hormones that inhibit cotton fiber development. Auxins, gibberellins, brassinosteriods and ethylene promote fiber growth (Figure 3, Lee et al., 2007). These compounds have other roles in plant development.

Cytokinin regulates cell division in roots and shoots, delays leaf senescence, promotes nutrient movement and chloroplast development (Taiz and Zeiger, 2006). In cotton, cytokinins promote ovule growth yet inhibit fiber development (Beasley and Ting, 1973; Chen et al., 1996). It is speculated that cytokinins promote initiation before fertilization but have no affect after fertilization (Lee et al., 2007).

ABA also inhibits cotton fiber growth. Dhindsa et al. (1975) identified potassium and malate to be major osmoregulatory solutes necessary in turgor maintence of the fiber cell. Dhindsa et al. (1976) studied the effects of ABA on potassium and malate transport into fibers. They concluded that ABA inhibited fiber growth by altering the potassium to malate ratio and possibly counteracting gibberellin activity.

Brassinosteriods (BR) are necessary for normal plant growth and development. In cotton, the hormone regulates fiber development by possibly regulating gene expression in cell elongation (Sun et al., 2005). Mitchell et al. (1970) discovered the promotion in stem elongation and cellular division from organic extracts from rapeseed (*Brassica mapus)* pollen, later isolated as a BR.

Ethylene is the phytohormone most noted for its role in fruit ripening. Synthetic forms have been used extensively as a commercial cotton harvest aid. In cotton, high levels of ethylene can inhibit boll retention resulting in potential yield loss whereas IAA tends to promote boll retention. In fibers, it can inhibit negative effects of cytokinins and ABA (Lee et al., 2007).

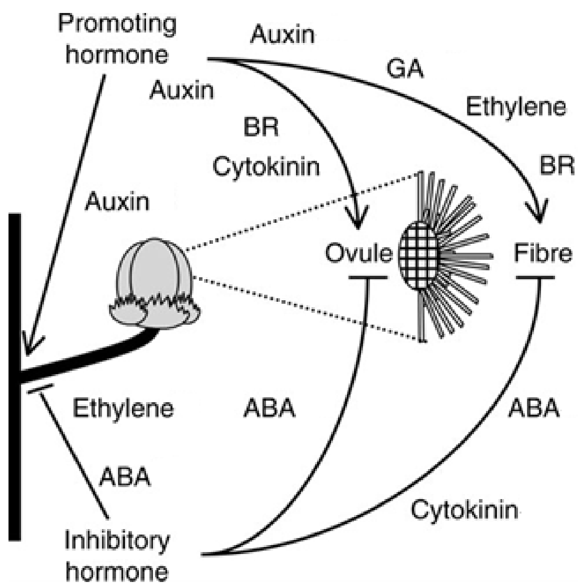

Figure 3. Hormonal impact on cotton development (Lee et al. 2007).

Gibberellins promote stem and cell elongation (Taiz and Zeiger, 2006). GA_3 is the most obtainable form of gibberellins and has been used in numerous experiments involving cotton fiber development in culture (Beasley and Ting, 1973; Davidonis, 1990; Chen et al., 1996). Gokani and Thaker (2002b) reported that GA_3 has an important role in regulating fiber elongation. Early work by Beasley and Ting (1973) showed the importance of IAA and GA_3 on fiber development in cultured cotton ovules. Unfertilized ovules failed to grow and produce fibers unless supplemented with these two hormones. In addition, GA_3 produced higher dry weights in treated ovules whereas IAA demonstrated higher fiber numbers (Dhindsa, 1978). Fertilized ovules in culture with constant GA_3 had the highest total number of fibers when IAA was added to the medium (Momtaz, 1998). The focus of this research project will be on IAA's role in the stages of cotton development.

IAA has been found to have a significantly higher concentration during the first days of fiber elongation in longer staple cultivars (Mead, 1994b; Naithani et. al, 1982; Gokani and Thaker, 2002a). *G. barbadense* has a 10x increase in IAA during elongation compared to that of *G. hirsutum* (Gould et al., 2000). *G. barbadense* plants typically produces a longer fiber than *G. hirsutum* plants. This implies a relationship between the amount of IAA present during primary elongation and final fiber length. Gokani and Thaker (2002a) increased fiber length of short staple cotton by applying IAA to the ovule.

IAA and IAA oxidase are up-regulated during primary elongation and inhibited during secondary cell wall development. IAA has been shown to be predominant during primary elongation and typically declines at the onset of secondary wall thickening (Naithani et al. 1982). IAA oxidase is the major catabolic enzyme for IAA. Several studies have demonstrated that IAA oxidase is expressed predominantly during secondary cell wall development. Increased concentration of ABA has been observed during formation of secondary cell wall development (Gould et al., 2000; Ruan, 2005). ABA inhibits fiber elongation; however, increased concentrations of IAA can overcome the inhibitory effects of ABA (Beasley and Ting, 1973).

John (1994) tried to observe changes in fiber properties by using transgenics as a means to increase IAA concentrations. The maximum amount of IAA, however, was produced at 15 dpa, which is generally past the peak of elongation, 10 dpa (Naithani et al., 1982). Exogenous application of IAA has been a useful strategy to determine the hormone's impact on fiber initials and ovules. Seagull and Giavalis (2004) exogenously applied IAA and GA_3 to cotton bolls grown in a greenhouse. These hormones were applied without the use of a surfactant on reproductive squares for pre-anthesis treatments, white flowers, and 1- 5 dpa for post-anthesis treatments. Ovules were harvested from 0 to 5 dpa, and fibers counted. Their results indicated an approximate 12% increase in fiber initials in the IAA post-anthesis treatment over the GA_3 pre-anthesis treatment and a 59% increase over the post-anthesis control. They concluded that increasing IAA during the first 5 dpa could potentially increase fiber production.

There are a number of environmental factors that influence cotton growth, development, and hormone production such as temperature, water availability and light. The optimum daytime temperature for cotton production is 28°C (Reddy et al., 1997). Early cotton fiber developmental phases are temperature dependent. Temperature influences the plant's metabolic rate and photorespiration, thus affecting boll development, and can influence the time between flower opening and boll opening (Gipson, 1986). Photorespiration occurs during times of high temperature, increases in pH and light; when CO_2 is limited. It competes with respiration for photoassimilates, in turn reducing plant growth. (Jensen, 1986).

Temperatures exceeding 28°C can cause faster metabolic rates which decrease the duration of fiber development, reducing the period between flower opening and boll opening. Rapid fiber development requires more photosynthate per day per unit of boll production (Ehlig, 1986). This limit's the plants ability to support its maximum fruiting capacity. As a result, competition for photoassimilate among developing bolls can lead to decreased boll retention and shedding of pre-anthesis reproductive structures. Cellulose, the main component of cotton fiber, is a β-linked glucose chain. Cellulose development produces a sink for photoassimilates (Delanghe, 1986). In theory, increasing fiber initiation would enhance cellulose production in turn creating a stronger reproductive sink.

Cool temperatures negatively affect fiber quality since cotton is thermophilic. Cool temperatures delay fiber initiation and early elongation (Haigler et al., 1991; Triplett, 2000), in turn promoting longer elongation periods (Xie, 1993). It also reduces the activity of several key enzymes needed for biochemical processes (Wang, 2009). The phase most adversely affected by cool temperatures, however, is secondary wall thickening (Martin and Haigler, 2004). There is a direct relationship between secondary wall thickness and fiber strength. When cotton is grown in below optimum temperature, the normal rate of cellulose deposition is decreased, promoting immature fibers, weak individual fiber strength and low micronaire values (Gipson, 1986).

Since cotton is a perennial species, in times of stress it will divert its energy away from reproductive activities and more towards survival mechanisms. This results in an increase of the vegetative to reproductive growth ratio (De Souza and da Silva, 1987). Water availability, nutrition, and soil-type play a role in the reproductive to vegetative ratio which affect yield (Hessler, 1961). Stress induced by water deficits adversely affects mineral nutrition uptake and hormonal flow which disrupts the hormone balance in the fruit abscission zone. This results in fewer nodes, reduced fruiting branches and fruiting sites on the cotton plant. In all plants under drought stress, the water potential of the individual cells becomes more negative. Rabadia et al. (1999) found a direct relationship between the available water uptake and the rate of dry matter accumulation in both fiber and seed index. Drought stress can reduce the maximum potential for primary fiber elongation which contributes to fiber length and yield potential.

Photosynthetic capacity of a crop is measured by the amount of light that enters the canopy (Sassenroth-Cole, 1995). Potential lint yield is lost when photoassimilates are limited by available light (Pettigrew, 1995). Such scenarios can occur during overcast days, shortened day lengths, or intraplant competition that limits light particularly in lower position fruit. The source-to-sink ratios are shifted in such a way that survival is prioritized over reproduction when light is limited. Shading experiments showed a decrease in both fiber strength and micronaire due to the limited photosynthetic capacity (Pettigrew, 2001, and Zhao and Oosterhuis, 2000).

CHAPTER III

METHODS TO APPLY IAA

A field study was conducted to characterize the effects of IAA on cotton fiber properties. The objective was to determine application techniques and practices for using IAA. It focused on IAA concentration, placement of treatment and the proper growth stage of the boll at which IAA should be applied.

Materials and Methods

A two-year field study was conducted at the Texas Agrilife Research farm in 2008 and 2009, to evaluate application practices of IAA. IAA concentrations were tested, along with proper placement and various ages of the developing boll. The cultivar 'Phytogen 355' (PSC 355) was chosen based on its average fiber length value and high yield potential (Haygood et al., 2000).

Plots, 3m x 12 m, were arranged in a randomized complete block with 3 replications per year. Planting occurred on 25 April in 2008 and on the 4 May in 2009. Seeds were planted in 1 m x 12 m row plots with a John Deere Max Emerge© cone planter. Seedlings were thinned to a final stand of 9 plants per meter.

The main treatment for this study was IAA concentration, the split-plot was placement of IAA, and the sub-split was date of administration. There were two IAA rates, 1x and 3x, and a control treatment consisting of KOH and water. IAA ($C_{10}H_9NO_2$, Sigma I-3750) was reconstituted with KOH and water to make a stock solution of 1mg/ml. It was further diluted to make working concentrations of 0.1 mg ml^{-1} (1x rate), and 0.3 mg ml^{-1} (3x rate). The control treatment consisted of KOH and water. All working concentrations and the control solution had a pH value of 9.

The IAA was placed either directly on the boll (OB) or on the apical meristem, annotated as over the top (OT). The treatment dates were 1) 4 days post anthesis (dpa), 2) 4 and 12 dpa and 3) 4, 12, and 20 dpa. It was applied at 4dpa to coincide with the start of primary fiber elongation and/or the start of secondary wall development, 12dpa and/or 20 dpa to coincide with the end of primary elongation. The purpose of having it applied two or three times was to promote uptake and determine if accumulation of IAA prevents or delays secondary wall thickening. Naithani et al. (1982) reported a decrease in IAA concentration before onset of secondary wall thickening.Plots consisted of an IAA concentration or the control treatment, with a placement treatment. Each row within the plot received a different date of application.

First position white flowers were tagged at random to represent 0 dpa. Ten drops of IAA solution or the control were applied using a transfer pipette at 1000 h (Seagull and Giavalis, 2004). One boll per plant was treated for each application. At least ten plants per row were used to provide enough lint for fiber analysis. Ten random first position open bolls from untreated plants were harvested to represent no treatment.

Treated bolls were harvested by hand as soon as bolls opened to reduce weathering effects. First position bolls located directly above and below bolls treated with IAA were harvested. This approach was taken to determine if the IAA treatment was translocated to adjacent bolls.

Seed cotton samples were processed on a laboratory roller gin. Lint percent was determined by dividing the lint cotton by the seed cotton weight. Seed index was calculated by the weight in grams of 100 fuzzy seed. Lint was analyzed by high volume instrumentation (HVI) at the Fiber and Biopolymer Research Institute in Lubbock, TX. HVI measured fiber micronaire, fiber length, length uniformity, fiber strength and elongation. Statistical analysis was done using SAS 9.2 with a mixed model and means were separated with Fisher LSD at a 95% confidence interval.

Results and Discussion

There were significant year effects on lint percent and seed index (Table 1). Fiber length had a significant interaction for Year*IAA*App*Date. HVI measured fiber properties showed significant year effects for micronaire and elongation. There was a significant two way interaction between year and date for fiber length uniformity. Fiber strength had a significant Year*IAA*App*Date interaction. There were no interactions for IAA*App*Date, which suggests no significant differences in concentration effects of IAA, the placement of IAA or when IAA was applied for lint percent, seed index or fiber length. As a result, treatment effects were combined across IAA concentration and analyzed against plants receiving no treatment by year.

Table 1. *P* values from analysis of variance of measured fiber properties for IAA applications to PSC 355 at College Station, TX, 2008-2009.

Source of variance	Lint Percent	Seed Index	Micronaire	Length	Uniformity	Strength	Elongation
	-------------------------------			PR>F	-------------------------------		
Year	0.0008	0.0060	0.0039	0.1267	0.0526	0.8750	<.0001
IAA	0.5720	0.3211	0.3720	0.9278	0.1795	0.6887	0.1073
Year*IAA	0.3844	0.6065	0.6436	0.6177	0.3172	0.4324	0.8537
App	0.4041	0.0945	0.9106	0.1102	0.2656	0.4942	0.5499
Year*App	0.4089	0.7122	0.9486	0.0983	0.1367	0.1125	0.8806
IAA*App	0.2528	0.1451	0.6212	0.2102	0.8474	0.9866	0.9781
Year*IAA*App	0.3322	0.6826	0.2757	0.9900	0.2911	0.4926	0.4869
Date	0.0835	0.1369	0.2492	0.1277	0.3176	0.0530	0.4284
Year*Date	0.8834	0.2430	0.2623	0.6363	0.0473	0.0212	0.3329
IAA*Date	0.6544	0.2178	0.1265	0.9655	0.3550	0.8746	0.8011
Year*IAA*Date	0.8712	0.2058	0.5211	0.0374	0.1481	0.8296	0.1296
App*Date	0.1434	0.3256	0.9425	0.8467	0.8757	0.9855	0.2112
Year*App*Date	0.6067	0.4545	0.6751	0.2307	0.6674	0.6828	0.9581
IAA*App*Date	0.5975	0.4562	0.2665	0.6647	0.3097	0.5141	0.3567
Year*IAA*App*Date	0.3807	0.3914	0.9715	0.5465	0.9606	0.0489	0.9441

Table 2. *P* values from analysis of variance of measured fiber properties. IAA versus No IAA effects on PSC 355 at College Station, TX, 2008-2009.

Year	Lint Percent	Seed Index	Micronaire	Length	Uniformity	Strength	Elongation
	-------------------------------			PR>F	-------------------------------		
2008	0.6662	0.0088	0.9971	0.9036	0.7650	0.9765	0.0621
2009	0.0004	<.0001	<.0001	0.0465	0.0793	0.4691	<.0001

In 2008, there were no significant differences in lint percent or HVI measured fiber properties (Table 2). There was a significant difference in seed index between untreated plants and those receiving IAA. In 2009, IAA affected all measured traits except fiber strength and fiber length uniformity. Perhaps plants responded positively to

IAA in 2009 than 2008, or the growing season interaction was more favorable to elicit a response to IAA applications.

Table 3. IAA effects on means of lint percent, seed index and fiber length for 2008 and 2009.

	Lint Percent		Seed Index		Length	
	%		g		mm	
	2008	2009	2008	2009	2008	2009
IAA	39.39 a[†]	36.08 b	10.0 b	8.8 b	28.05 a	27.19 b
NO	39.26 a	37.70 a	10.3 a	9.3 a	28.11 a	27.61 a

[†]Within groups, means followed by the same letter do not differ at *P* =0.05.

Plants treated with IAA had significantly lower seed indices in comparison to non-treated plants in both years (Table 3). It was originally hypothesized that lint percent would increase in response to IAA applications. Instead, lint percent significantly decreased with the IAA application in 2009. Fiber length decreased slightly in response to IAA application in 2009 (Table 4). It was thought that IAA would amplify the phases of initiation and primary elongation, in turn increasing yield and fiber length, but data from 2009 contradicted that original hypothesis.

Table 4. IAA effects on means of HVI measured fiber properties for 2008 and 2009.

	Micronaire		Uniformity		Strength		Elongation	
			%		kN m kg^{-1}		%	
	2008	2009	2008	2009	2008	2009	2008	2009
IAA	5.5 a†	4.7 b	85.6 a	84.8 a	308 a	304 a	9.24 a	7.35 b
NO	5.5 a	5.1 a	85.6 a	85.3 a	307 a	310 a	9.00 a	10.99 a

†Within groups, means followed by the same letter do not differ at P =0.05.

Fiber micronaire from plants treated with IAA had lower fiber micronaire than fiber from non-treated plants in 2009. From a marketing standpoint this was a desirable result since the 'No treatment' mean had a relatively high fiber micronaire (>5.0). Fiber at this level is undesirable for textile processing of high quality yarn. Fiber length uniformity and fiber strength were unchanged in comparison to non-treated results by the application of IAA, while elongation decreased with the IAA application.

Non-treated bolls located directly above and below treated bolls were sampled. Application of IAA on cotton may have partially translocated to adjacent bolls, or the IAA may have altered the source-sink balance within the plant in such a way that adjacent bolls were affected. In 2008, bolls were ginned and lint percent determined along with seed index, but no fiber information was ascertained from this year. In 2009, all fiber properties were measured. Each IAA concentration, application locations, and date treatments were tested against above and below bolls. In Tables 5, 6 and 7, IAA treatments are annotated as Tmt and position indicates above and below.

Table 5. *P* values from analysis of variance of lint percent and seed index for IAA position effects on PSC 355 at College Station, TX, 2008-2009.

Source of variance	Lint Percent	Seed Index
	------------ PR>F	-----------
Year	0.0010	0.0005
Tmt	0.1879	0.7289
Year*Tmt	0.9306	0.0823
Position	<.0001	0.0204
Year*Position	0.0510	<.0001
Tmt*Position	0.6750	0.4710
Year*Tmt*Position	0.8799	0.2970

Table 6. *P* values from analysis of variance of lint percent and seed index for IAA position effects for PSC 355 in College Station, TX, 2008.

Source of variance	Lint Percent	Seed Index
	------------- PR>F	-----------
Tmt	0.3821	0.2511
Position	<.0001	0.1861
Tmt*Position	0.4222	0.4273

The ANOVA for lint percent and seed index indicates that the effect of ‘year’ was significant for both traits (Table 5). In addition, ‘position’ had significant effects lint percent and seed index. Finally, the ANOVA reveals significant interaction between year and position for seed index.

The fruiting position of the boll affected lint percent, but not seed index in 2008 (Table 6). IAA did not have a significant effect upon seed index in 2008. Analysis of the boll positions in relation to IAA indicated no significant interactions. A cotton plant typically produces fiber quality gradient in which quality tends to decline with advancing boll positions. Lint percent is largely a function of seed size and fibers per surface area. Lint percent was higher in bolls below the IAA- treated boll. Lint percent was not significantly different in bolls from above the IAA treated in comparison to the treated bolls (Table 7). Seed index was slightly less than bolls from above the IAA treatment. Seed indices were similar from the IAA treated bolls and those from non-treated bolls sampled at lower fruiting positions.

Table 7. IAA position effects on means of lint percent and seed index in 2008.

Year	Position	Lint Percent	Seed Index
		%	g
2008	Above	39.50 b†	10.3 ab
2008	Main	39.41 b	10.0 b
2008	Below	41.90 a	10.1 ab

†Within groups, means followed by the same letter do not differ at *P* =0.05.

In 2009, seed index was significantly different between IAA treated plants and non-treated plants (Table 8). Bolls above and below the IAA-treated boll were significantly different with regard to lint percent and seed index. The IAA treatment effect was not significant for lint percent. There were no significant interactions for treatment*position effects.

Table 8. *P* values from analysis of variance of measured fiber properties for IAA position effects on PSC 355 at College Station, TX, 2009.

Source of variance	Lint Percent	Seed Index	Micronaire	Length	Uniformity	Strength	Elongation
	----------	----------	----------	PR>F	----------	----------	----------
Tmt	0.6559	0.0089	0.5564	0.9230	0.8567	0.8369	0.5740
Position	0.0496	0.0007	0.1228	0.0056	0.3093	0.0406	<.0001
Tmt*Position	0.9451	0.7975	0.5672	0.0659	0.7480	0.3158	0.6117

The application of IAA in 2009 on PSC 355 did not have a significant effect on fiber micronaire, length, length uniformity, strength, and elongation. The position effect was significant upon fiber length, strength and elongation. There were no significant interactions between treatment and position for any HVI measured fiber properties.

Table 9. IAA position effects on means of lint percent, seed index and fiber length in 2009.

Year	Position	Lint Percent	Seed Index	Length
		%	g	mm
2009	Above	37.94 a†	8.6 c	26.90 b
2009	Main	36.09 b	8.9 b	27.68 a
2009	Below	37.79 ab	9.2 a	27.21 b

†Within groups, means followed by the same letter do not differ at *P* =0.05.

Based on 2008 data, lint percent was expected to increase on lower positioned bolls, but lint percent results in 2009 were different. The IAA treated bolls had a significantly lower lint percent than untreated bolls above (Table 9). In addition, lower bolls failed to surpass upper bolls in terms of lint percent. Seed indices declined as boll position progressed up the plant. Interestingly, fiber length in 2009 was longer from IAA-treated bolls than non-treated bolls above and below.

Table 10. IAA position effects on means of HVI measured fiber properties in 2009.

Year	Position	Micronaire	Uniformity	Strength	Elongation
			%	kN m kg–1	%
2009	Above	5.0 a†	84.9 a	297 b	11.00 a
2009	Main	4.7 a	84.8 a	307 ab	7.36 b
2009	Below	4.9 a	85.3 a	323 a	11.00 a

†Within groups, means followed by the same letter do not differ at P =0.05.

Lower quality fiber is expected to be generated from upper position bolls, seen in fiber strength (Bednarz et al., 2006). Micronaire and uniformity was relatively unaffected by positional effects, having no significant differences between location of the bolls (Table 10). The exception was for fiber elongation. IAA treated bolls had significantly less elongation in comparison to non-treated bolls both above and below.

Conclusion

IAA concentration, application method and date had no effect on measured traits on the genotype (PSC 355). The 1x rate and 3x rate were combined and tested against non treated bolls. In 2008, there was only significant IAA effect on seed index; in 2009 all traits except length uniformity and fiber strength were affected by IAA applications.

The difference between years could be due to the hotter growing season of 2009 or possibly the integrity of the IAA stock solution. Assuming the IAA stock solution was better in 2009, it is possible that the hotter temperatures may have had deleterious effects on the IAA's ability to positively affect fiber initiation and elongation phases.

There did not appear to be IAA translocation or other physiological effects on adjacent bolls. Fiber quality is higher on lower positioned bolls (Bednarz et al., 2006); this was seen within the study. However there was an increase in fiber length and decrease in fiber elongation within the IAA treated bolls. An explanation for fiber length could be caused by higher sink strength, limiting resources from the fruiting site below.

It was hypothesized that IAA exogenously applied would improve fiber quality in the form of yield and increased fiber length. In this particular genotype, PSC 355, it was not the case. Instead fiber yield and quality decreased. Further work needs to be done to effectively understand IAA's role in fiber development. Perhaps other genotypes may be better suited for exogenous IAA application.

CHAPTER III

EFFECT OF EXOGENOUSLY APPLIED AUXIN ON DIFFERENT UPLAND COTTON GENOTYPES

A two year field study was conducted to determine the effects of auxin on yield components and fiber quality parameters in five genotypes with a wide range of fiber length potential.

Materials and Methods

Field studies were conducted on a Weswood silt loam, a fine-silty, mixed, superactive, thermic Udifluventic Haplustepts intergraded with Ships very-fine, mixed, active, thermic chromic Hapluderts at the Texas Agrilife Research Farm near College Station, TX, in 2008 and 2009, to evaluate effects of IAA on five contrasting genotypes: : TAM 94L-25-$M_{3:5}$-9469, TAM 94L-25-$M_{3:5}$-9505, TAM 94L-25-$M_{3:5}$-9653,TAM94L-25 (Smith, 2003; PI 631440), and TAM B182-33 ELS (Smith, et al., 2009). TAM94L-25 is a breeding line released in 2003 that has been extensively used as a parental line within many cotton breeding programs. TAM 94L-25-$M_{3:5}$-9469, TAM 94L-25-$M_{3:5}$-9505, TAM 94L-25-$M_{3:5}$-9653 are sister lines selected from a chemically mutated population of TAM94L-25 in 2000. These mutant sister-lines have significantly different fiber length potentials, but other fiber traits are relatively similar. TAMB182-33 (ELS) is an upland breeding line with fiber length often exceeding 1.375, which is the minimum fiber length for pima, *G. barbadense.*

The field trial was arranged in a randomized complete block design with 4 replications. Entries were grown in single row plots, 1m x 12m. The trial was planted on 25 April in 2008 and on 4 May in 2009. Seeds were planted with a John Deere Max Emerge© planter fitted with research cone seed metering units. Seedlings were thinned for uniformity to nine plants meter^{-1}.

IAA ($C_{10}H_9NO_2$, Sigma I-3750) was reconstituted with KOH to a working concentration of 0.1mg ml^{-1} (1x rate). A working solution was made by diluting a stock solution of 1mg ml^{-1}. Slight modifications in the frequency of reconstituting the solution were made in the second year to improve efficiency of the product.

It was applied directly to bolls at 4 dpa to coincide with the start of primary fiber elongation; at 12 dpa, to coincide with the start of secondary wall development, and at 20 dpa to coincide with the end of primary elongation. The purpose of the three applications was to promote uptake and determine if repeated exposure to supplemental IAA prevents or delays secondary wall thickening. Naithani et al. (1982) reported a decrease in IAA concentration before onset of secondary wall thickening. Increasing IAA applications may delay secondary wall thickening.

First position white flowers were tagged and dated to represent 0 dpa. Ten drops of IAA solution were applied mid-morning using a transfer pipette on 4, 12 and 20 dpa. One boll per plant was treated and a total of ten plants per plot were treated to provide enough lint for fiber analysis. First position bolls on non-treated plants were chosen as experimental control units. Treated and control bolls were harvested by hand as soon as bolls opened to mitigate weathering effects.

Seed cotton was processed on a laboratory saw gin. Lint percent was calculated as lint weight/seed cotton weight. Seed index was measured as seed index (grams) of 100 fuzzy seeds. Fiber samples were analyzed using high volume instrumentation (HVI) at the Fiber and Biopolymer Institute in Lubbock, TX. HVI measured fiber micronaire, length, strength, length uniformity, and elongation.

Data were analyzed using the mixed procedure in SAS 9.2. and means separated using pairwise LSD comparisons at p=0.05.

Results and Discussion

There were significant differences for both lint percent and seed index among genotypes (Table 11). The difference due to genotype effect was expected since the genotypes for this study were chosen based on fiber length potential. IAA treatment effects were significant for seed index and had a p-value of 0.057 for lint percent. Lint percent was significantly different for year*IAA. This could be due to different types of growing seasons, with 2009 being generally warmer than 2008, and the improved IAA stock used the later season.

Fiber traits were affected by year, genotype, and year*IAA. A significant genotype effect was to be expected since the genotypes were originally selected on the basis of fiber trait diversity. The year*genotype effect caused significant differences for fiber micronaire, and elongation. IAA had significant effects on all fiber traits except length uniformity. Interestingly, genotype*IAA effects elicited a significant difference for fiber elongation at p=<.0001. This was the only fiber property significantly affected by this interaction. Lastly there was a significant three way interactions of year*genotype*IAA for fiber micronaire, strength and elongation.

Table 11. *P* values from analysis of variance of measured fiber properties for IAA applications on different genotypes at College Station, TX, 2008-2009.

Source of variance	Lint Percent	Seed Index	Micronaire	Length	Uniformity	Strength	Elongation
	----------	----------	----------	PR>F	----------	----------	----------
Year	0.4057	0.9980	<.0001	0.0006	0.0032	0.0770	<.0001
Genotype	<.0001	<.0001	<.0001	<.0001	0.0002	<.0001	<.0001
Year*Genotype	0.5076	0.8618	0.0006	0.6643	0.2434	0.0753	<.0001
IAA	0.0572	0.0019	<.0001	0.0037	0.1471	0.0455	<.0001
Year*IAA	<.0001	0.1873	<.0001	0.0010	0.0092	<.0001	<.0001
Genotype*IAA	0.6004	0.8222	0.8370	0.1026	0.5133	0.1110	<.0001
Year*Genotype*IAA	0.5822	0.9458	0.0235	0.9129	0.2995	0.0011	0.0049

Table 12. *P* values from analysis of variance of measured fiber properties for IAA applications on different genotypes at College Station, TX, 2008.

Source of variance	Lint Percent	Seed Index	Micronaire	Length	Uniformity	Strength	Elongation
	----------	----------	----------	PR>F	----------	----------	----------
IAA	0.0041	0.4899	0.7061	0.5574	0.2144	<.0001	<.0001
Genotype	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Genotype*IAA	0.5638	0.3657	0.0748	0.6995	0.2718	0.0001	<.0001

Because of significant year interactions, data from 2008 and 2009 were analyzed separately (Tables 12 and 13). While the growing seasons for 2008 and 2009 were similar in the amount of precipitation, the daily maximum temperature was generally 5°

C higher in 2009 than 2008. As temperature increases, the rate of development from flower to open boll increases (Gipson,1986). Couple this with the potentially higher rate of photorespiration that can occur in warmer temperatures and the year interactions were not unexpected.

In 2008, there were significant differences for IAA effects of lint percent, fiber strength and elongation (Table 12). Significant differences among genotypes for all measured traits were again ascertained from 2008 data. Significant interactions for genotype*IAA were detected for fiber strength and elongation.

In 2009, significant genotype differences were observed for lint percent, seed index, fiber length uniformity, and strength (Table 13). Surprisingly significant differences for fiber micronaire, length, and elongation were detected as was not the case in 2008. IAA treatments in 2009 resulted in significant differences for all measured traits, in contrast to 2008 results in which only lint percent, fiber strength and elongation were significantly different. The interaction of genotype*IAA in 2009 indicated only a difference for seed index at p=0.095.

Table 13. *P* values from analysis of variance of measured fiber properties for IAA applications on different genotypes at College Station, TX, 2009.

Source of variance	Lint Percent	Seed Index	Micronaire	Length	Uniformity	Strength	Elongation
	----------------	----------------	----------------	PR>F	----------------	----------------	----------------
IAA	0.0024	<.0001	<.0001	0.0024	0.0495	0.0171	0.0047
Genotype	0.0058	<.0001	0.0415	<.0001	0.0004	0.0005	<.0001
Genotype*IAA	0.6677	0.095	0.2357	0.5968	0.8621	0.5651	0.4453

IAA Effects

In 2008, the traits affected by IAA applications were lint percent, fiber strength and elongation. Lint percent and fiber elongation decreased with the IAA treatment, while fiber strength increased (Tables 14 and 15). This was unexpected since it was hypothesized that additional IAA would increase lint percent. It is not uncommon to see an inverse relationship between strength and elongation. Fiber strength is related to the crystalline structure of the fibers while elongation is a measure of elasticity in the fibers. Stronger fibers could cause quicker breakage when stretched, decreasing elongation measurements.

Table 14. IAA versus No IAA treatment effects of lint percent, seed index and fiber length at College Station, TX, 2008-2009.

	Lint Percent		Seed Index		Length	
	%		g		mm	
	2008	2009	2008	2009	2008	2009
IAA	35.3 b[†]	39.1 a	12.4 a	9.6 b	31.9 a	28.2 b
No IAA	37.1 a	34.8 b	12.1 a	11.2 a	31.6 a	29.9 a
CV,%	8.1	22.8	10.5	12.5	9.4	8.9

[†]Within groups, means followed by the same letter do not differ at *P* =0.05.

Table 15. IAA versus No IAA treatment effects of HVI measured properties at College Station, TX, 2008-2009.

	Micronaire		Uniformity		Strength		Elongation	
			%		kN m kg^{-1}		%	
	2008	2009	2008	2009	2008	2009	2008	2009
IAA	4.5 a[†]	3.0 b	83.8 a	80.8 b	323 a	290 b	5.39 b	4.48 b
No IAA	4.5 a	3.9 a	83.4 a	82.1 a	308 b	318 a	7.05 a	5.00 a
C.V.,%	7.5	15.2	1.7	2.9	7.9	12.9	23.7	16.9

[†]Within groups, means followed by the same letter do not differ at P =0.05.

In 2009, IAA affected all measured properties. In contrast to 2008, lint percent was the only property that increased while all other properties decreased. The improvement in lint percent from plants treated with IAA suggests that fiber initiation was amplified as reported by Giavalis and Seagull (2001). However increased fiber initiation does not necessarily mean increases in mature fiber or an overall improvement of fiber quality. It is possible the additional fiber initiation caused the incidence of fuzz fibers or immature fibers to increase. Another consideration to explain greater lint percent may be due to smaller seed index from plants treated with IAA. Smaller seed tends to increase lint percent. It is also possible to have a decrease in the number of seeds per boll with IAA application (Pandey et al., 2003).

Genotype Effects

In 2008, lint percent was not different ($p<0.05$) among the genotypes included in this study and ranged from 33.3 to 35.4 (Table 16). The rank among the genotypes changed with improvements in TAM94L25 and 9505. ELS and 9505 had the lowest lint percents that remained constant with the IAA treatment, while 9469 remained constant with the highest lint percent. Seed index increased in 9505, ELS and TAM94L25. IAA did not affect 9563 in terms of seed index relative to other genotypes. The rank among genotypes increased in 9469, 9505 and TAM94L25. In response to IAA, seed index increased TAM94L25 in rank, making it no different than ELS. The line 9505 increased with IAA to be comparable to TAM94L25 and 9563.

Table 16. Genotype response to IAA of lint percent, seed index and fiber length at College Station, TX, 2008.

Genotype	Lint Percent		Seed Weight		Length	
	%		g		mm	
	IAA	No IAA	IAA	No IAA	IAA	No IAA
9469†	38.7 ab‡	41.1 a	10.1 c	10.0 d	30.6 b	29.7 c
9505§	35.0 bc	35.4 c	12.3 b	12.0 c	28.2 c	28.8 c
9563¶	33.3 c	35.4 c	12.5 b	12.5 b	32.4 b	32.8 b
ELS#	32.7 c	35.6 c	14.0 ab	13.5 a	36.4 a	36.0 a
Tam94L25††	37.3 ab	37.8 b	13.2 ab	12.6 b	31.9 b	30.9 bc
C.V.,%	8.43	7.14	11.72	9.37	9.50	9.44

†TAM 94L-25-$M_{3:5}$-9469

‡Within groups, means followed by the same letter do not differ at *P* =0.05.

§TAM 94L-25-$M_{3:5}$-9505

¶TAM 94L-25-$M_{3:5}$-9653

#TAM B182-33 ELS

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The genotype*IAA interaction for fiber length in 2008 was not significant at p=0.05. There was a change in the rank of genotypes. IAA appeared to be more efficacious for 9469 than for 9505. The rank of 9469 improved with IAA treatment as fiber from this genotype went from 29.7 mm without IAA to 30.6 mm with IAA applications.

Table 17. Genotype response to IAA of HVI measured fiber properties at College Station, TX, 2008.

Genotype	Micronaire		Uniformity		Strength		Elongation	
			%		kN m kg^{-1}		%	
	IAA	No IAA	IAA	No IAA	IAA	No IAA	IAA	No IAA
9469†	4.3 b‡	4.5 a	84.0 ab	83.2 b	300 d	277 d	6.27 a	8.65 a
9505§	5.0 a	4.7 a	82.7 b	82.4 b	313 cd	294 c	5.95 ab	7.83 b
9563¶	4.3 b	4.5 a	83.0 b	82.9 b	323 bc	310 b	5.20 bc	7.05 b
ELS#	4.0 b	4.2 b	84.9 a	85.7 a	340 a	357 a	4.95 c	4.40 c
Tam94L25††	4.9 a	4.7 a	84.2 ab	82.9 b	336 ab	301 bc	4.60 c	7.30 b
C.V.,%	9.24	5.84	1.52	1.81	5.43	9.18	14.23	21.90

†TAM 94L-25-M$_{3:5}$-9469

‡Within groups, means followed by the same letter do not differ at *P* =0.05.

§TAM 94L-25-M$_{3:5}$-9505

¶TAM 94L-25-M$_{3:5}$-9653

#TAM B182-33 ELS

In the absence of exogenously placed IAA treatments, all genotypes had fiber micronaire values greater than ELS in 2008 (Table 17). The application of IAA resulted in fiber micronaire from 9469 and 9563 becoming no different than fiber from ELS. Micronaire readings (>5.0) can indicate coarse fibers and are not desired for fine-count yarns (May, 1999). Therefore the reduction in fiber micronaire would be a positive alteration if it was the result of finer fiber, but deleterious if caused by less mature fibers. Uniformity in fiber length is a desirable trait for textile processing. IAA had little effect upon fiber length uniformity. With the addition of IAA, 9469 and TAM94L25 were similar to ELS in fiber length uniformity.

All genotypes showed a general improvement of fiber strength in response to IAA. Fiber strength, in 2008, had a significant genotype*IAA interaction with a p-value of 0.0001 (Table 17). The fiber strength of TAM94L25 improved in relation to ELS, from 30.7g/tex to 34.2g/tex with IAA treatment. Fiber elongation among all genotypes generally decreased with IAA treatments. Fiber from ELS had the lowest percent elongation both with and without IAA applications.

Table 18. Genotype response to IAA of lint percent, seed index and fiber length at College Station, TX, 2009.

Genotype	Lint Percent		Seed Index		Length	
	%		g		mm	
	IAA	No IAA	IAA	No IAA	IAA	No IAA
9469†	43.5 a‡	38.7 a	9.0 b	9.9 c	28.3 b	28.6 bc
9505§	37.7 a	32.5 c	8.9 b	11.0 b	25.4 c	27.1 c
9563¶	36.3 a	33.5 c	9.7 ab	11.2 b	28.1 b	30.8 b
ELS#	36.4 a	33.5 c	10.9 a	12.4 a	32.1 a	33.5 a
Tam94L25††	42.9 a	35.6 b	9.3 b	11.6 ab	27.3 bc	29.5 b
C.V.,%	11.60	7.27	11.49	8.77	9.09	8.69

†TAM 94L-25-$M_{3:5}$-9469

‡Within groups, means followed by the same letter do not differ at *P* =0.05.

§TAM 94L-25-$M_{3:5}$-9505

¶TAM 94L-25-$M_{3:5}$-9653

#TAM B182-33 ELS

In 2009, IAA had a positive effect among all genotypes for lint percent. The coefficient of variation went from 7.27% without IAA to 11.60% with IAA. In addition, the application of IAA resulted in no significant differences among genotypes for lint percent. The gain in lint percent confirms the findings of Seagull and Giavalis (2004).

Seed index had the only significant genotype*IAA interaction ($p>0.05$) in 2009 (Table 18). Seed indices decreased in all genotypes with the application of IAA. The line of 9469 showed the least amount of seed index loss in response to IAA. Seed size is arbitrary. If reductions in size are not offset by increased yield, than it is a negative. Coefficient of variations increased among plants treated with IAA .

IAA reduced fiber length among all genotypes. It was originally thought that IAA would improve fiber length. There was few rank changes among this set of genotypes treated with IAA.

IAA treatment reduced fiber micronaire values among all genotypes and resulted in no significant differences (Table 19). The coefficient of variation went from 7.82% with no IAA to 12.98% with the application of IAA. Many of the genotypes in 2008 produced fiber with an undesirable high micronaire. In 2009, the fiber micronaire, especially from plants treated with IAA, was unusually low. Low micronaire values (<3.5) are indications of immature fibers. Immature fibers are undesirable because they can cause neps- entanglements within the fabric (May, 1999).

Table 19. Genotype response to IAA of HVI measured fiber properties at College Station, TX, 2009.

Genotype	Micronaire		Uniformity		Strength		Elongation	
			%		kN m kg–1		%	
	IAA	No IAA	IAA	No IAA	IAA	No IAA	IAA	No IAA
9469[†]	3.5 a[‡]	4.0 ab	82.1 a	82.1 a	293 ab	298 b	5.31 a	5.80 a
9505[§]	2.9 a	3.9 abc	77.0 b	78.9 b	258 b	303 b	4.89 ab	5.68 a
9563[¶]	2.9 a	3.6 c	80.9 ab	83.1 a	286 ab	330 ab	3.95 bc	4.55 b
ELS[#]	3.1 a	3.8 bc	82.9 a	83.8 a	352 a	357 a	4.80 ab	4.78 b
Tam94L25[††]	3.0 a	4.2 a	80.8 ab	82.6 a	263 b	302 b	3.43 c	4.20 b
C.V.,%	12.98	7.82	3.05	2.82	16.05	10.42	17.41	15.46

[†]TAM 94L-25-$M_{3:5}$-9469

[‡]Within groups, means followed by the same letter do not differ at *P* =0.05.

[§]TAM 94L-25-$M_{3:5}$-9505

[¶]TAM 94L-25-$M_{3:5}$-9653

[#]TAM B182-33 ELS

IAA had a negative effect on fiber length uniformity across genotypes. The interaction of genotype and IAA treatments were slightly significant. There was no substantial increase in the coefficient of variation with IAA as was the case with some of the other measured traits. Fiber strength among all genotypes was less in plants treated with IAA. Rankings among lines were fairly stable. The coefficient of variation was greater for IAA treated plants.

Fiber elongation in 2009 was slightly reduced by IAA. Tam 94L25 had the lowest elongation both with and without IAA applications. The coefficient of variation has relatively high for fiber traits under both systems with the IAA treated plants being slightly higher than plants without IAA.

Conclusion

Differences among the years can possibly be contributed to environmental conditions, with 2009 being much hotter season than 2008 (Tables 20 and 21, Appendix A). Hotter temperatures increase rates of metabolic processes and cause rapid fiber development. It can shorten the time between fertilization and boll opening (Ehling, 1986). Altering the time periods of primary elongation and secondary wall thickening may account for decreases in fiber strength in 2009.

It was hypothesized that IAA could increase fiber initiation and elongation. The application of IAA slightly decreased lint percent in a 2008 while increasing it in all genotypes in 2009. The data suggests that IAA stock solution was more effective and that plants responded better.

For the 2009 season, the results indirectly support Seagull and Giavalis (2004) in that increased fiber initials would account for the increase in lint percent. Exogenously applied IAA provided a potential yield increase by negatively affecting fiber quality for PSC 355. Further work needs to be done to determine IAA’s role in the fiber development phases. Investigating the amount of IAA translocation within the boll will help improve fiber initiation and primary elongation.

CHAPTER V

SUMMARY AND CONCLUSIONS

IAA plays an important role in fiber development as noted in the literature review. Understanding and utilizing IAA to promote maximum fiber quality potential will require extensive research. Applying IAA exogenously in a field environment at the present time is futile. This research has shown that genotypes respond differently to IAA and that favorable results are achievable.

REFERENCES

Applequist, W.L., R. Cronn, and J. F. Wendel. 2001. Comparative development of fiber in wild and cultivated cotton. Evolution and Development. 3:3-17.

Beasley, C.A. and I.P. Ting. 1973. The effects of plant growth substances on *in vitro* fiber development from fertilized cotton ovules. Amer. J. Bot. 60: 130-139.

Bednarz, C., R. Nichols, and S. Brown. 2006. Plant density modifies with in canopy-cotton fiber quality. Crop Sci. 46:950-956.

Berlin, J.D. 1986.The outer epidermis of the cottonseed. p. 375-414. *In*: Mauney J.R. and Stewart J. McD. (eds.) Cotton Physiology. The Cotton Foundation, Memphis, TN.

Birnbaum, E.H., C.A. Beasley, W.M. Dugger. 1974. Boron deficiency in unfertilized cotton (*Gossypium hirsutum*) ovules grown *in vitro*. Plant Physiology. 54:931-935.

Chen, J.G., X.M. Du, H.Y. Zhao, and X. Zhou. 1996. Fluctuation in levels of endogenous plant hormones in ovules of normal and mutant cotton during flowering and their relation to fiber development. J. Plant Growth Regul. 15:173-177.

Davidonis, G.H. 1990. Gibberellic acid-induced cell elongation in cotton suspension cultures. J. of Plant Growth Regul. 9:243-246.

DeLanghe, E.A.L. 1986. Lint development. p. 325-349. *In:* Mauney J.R. and Stewart J. McD. (eds.) Cotton Physiology. The Cotton Foundation, Memphis, TN.

De Souza, J.G. and J. Vieira da Silva. 1987. Partitioning of carbohydrates in annual and perennial cotton (*Gossypium hirsutum* L.). J. Exp. Bot. 38:1211-1218.

Dhindsa, R.S., C.A. Beasley, and I.P. Ting. 1975. Osmoregulation in cotton fiber. Accumulation of potassium and malate during growth. Plant Physiol. 56:394-398.

Dhindsa, R.S., C.A. Beasley, and J.P. Ting. 1976. Effects of abscisic acid on *in vitro* growth of cotton fiber. Planta. 130:197-201.

Dhindsa, R.S. 1978. Hormonal regulation of cotton ovule and fiber growth: Effects of bromodeoxyuridine, AMO-1618 and p-chlorophenoxyisobutyric acid. Planta. 141:269-272.

Ehlig, C. F. 1986. Influence of atmospheric parameters on growth and development. p. 57-62.*In*: Mauney J.R. and Stewart J. McD. (eds.) Cotton Physiology. The Cotton Foundation, Memphis, TN.

Gialvalis, S. and R.W. Seagull. 2001. Plant hormones alter fiber initiation in unfertilized, cultured ovules of *Gossypium hirsutum*. J. of Cotton Sci. 5:252-258.

Gipson, J.R. 1986. Temperature effects on growth, development, and fiber properties. p. 47-56. *In*: Mauney J.R. and Stewart J. McD. (eds.) Cotton Physiology. The Cotton Foundation, Memphis, TN.

Gokani, S.J. and V.S. Thaker. 2002a. Physiological and biochemical changes associated with cotton fiber development IX. Role of IAA and PAA. Field Crops Res. 77:127-136.

Gokani, S.J. and V.S. Thaker. 2002b. Role of gibberellic acid in cotton fibre development. J. Agric. Sc. 138:255-260.

Gould, J.H., H.Slator, R.H. Smith, and P. Morgan. 2000. Unbound IAA and ABA in developing seeds and fibers of Gossypium hirsutum and Gossypium barbadense. Proceedings Cotton Seed Biotechnology Conference. San Antonio, TX.

Haigler, C.H., N.R. Rao, E.M. Roberts, J. Huang, D.R. Upchurch, and N.L. Trolinder. 1991. Cultured ovules as models for cotton fiber development under low temperatures. Plant Physiol. 95:88-96.

Haigler, C.H. 2007. Substrate supply for cellulose synthesis and its sensitivity in the cotton fiber. p.147-168. *In*: R.M. Brown and I.M. Saxena (eds.) Cellulose: Molecular and Structural Biology. Springer, New York, NY.

Haygood, R., R. McPherson, and E. Lubbers. 2001. Phytogen 355-2000 update. 1:400-402. Proceedings of Beltwide Cotton Conference. 4-9 Jan. 2001. Anaheim, CA. National Cotton Council. Memphis, TN.

Hessler, L.E. 1961. The relationship between cotton fiber development and fiber properties. Textile Res. J. 38-43.

Hsieh. Y-L. 1999. Strustural development of cotton fibers and linkages to fiber quality. p. 137-165.*In:* Basra (ed.) A.S. Cotton fibers: developmental biology, quality improvement, and textile processing. Food Products Press. New York, NY.

Jasdanwala, R.T., Y.D.Singh, and J.J. Chinoy. 1977. Auxin metabolism in developing cotton hairs. J. Exp. B. 28:1111-1116.

Jenson, R.G. 1986.The outer epidermis of the cottonseed. p. 375-414. *In*: Mauney J.R. and Stewart J. McD. (eds.) Cotton Physiology. The Cotton Foundation, Memphis, TN.

John, M.E. 1994. Progress in genetic engineering of cotton for fiber modification. 1:292-296. Challenging the Future: Proceedings of the World Cotton Conference. 14-17 Feb. 1994. Brisbane, Aus. CSIRO, Melbourne, Aus.

Lee, J.J., A. W. Woodard, and Z. J. Chen. 2007. Gene expression changes and early events in cotton fibre development. Annals of Botany. 100:1391-1401.

Martin, L.K, and C.H.Haigler. 2004. Cool temperature hinders flux from glucose to sucrose during cellulose synthesis in secondary wall stage cotton fibers. Cellulose. 11:339-349.

May, O.L. 1999. Genetic variation in fiber quality. p.183-229. *In*: A.S. Basra (ed.) Cotton Fibers. Food Products Press. New York, NY.

May, O.L., and G.M. Jividen. 1999. Genetic modification of cotton fiber properties measured by single- and high- volume instruments. Crop Sci. 39:328-333.

Mitchell, J. W., Mandava, N. B . , Worley, J. F., Plimmer, J. R., Smith, M. V. 1970. Brassins: A new family of plant hormones from rape pollen. Nature. 225: 1065-1066.

Moharir, A.V., M. Bodas, A. Vashisth. 2003. Rate and amount of cellulose synthesis in developing fibers of *Gossypium arboretum* and *Gossypium hirsutum* cotton. J. of Applied Polymer Sci. 90:1453-1462.

Momtaz, O.A. 1998. Effect of plant growth regulators on *in vitro* fiber development from unfertilized and fertilized Egyptian cotton ovules. Plant Growth Regulation. 25:159-164.

Naithani, S.C., N.R. Rao, and Y.D. Singh. 1982. Physiological and biochemical changes associated with cotton fibre development. Physiol. Plant. 54:225-229.

Panday, D.M., C.L. Goswami, and B. Kumar. 2003. Physiological effects of plant hormones in cotton under drought . Biologia Plantarum. 47:535-540.

Pettigrew, W.T. 1995. Source-to-sink manipulation effects on cotton fiber quality. Agron. J. 87:947-952.

Pettigrew, W.T. 2001. Environmental effects on cotton fiber carbohydrate concentration and quality. Crop Sci. 41:1108-1113.

Rabadia, V.S., V.S. Thaker, and Y.D. Singh. 1999. Relationship between water content and growth of seed and fibre of three cotton genotypes. J. Agronomy and Crop Science. 183: 255-261.

Reddy, K.R., H.F. Hodges, and J.M. McKinion. 1997. Crop modeling and applications: A cotton example. p. 225-290. *In* D. Sparks(ed.) Advances in Agronomy. 57. Academic Press, San Diego, CA.

Ruan, Y. 2005. Recent advances in understanding cotton fibre and seed development. Seed Science Res. 15:269-280.

Sassenroth-Cole, G. F., Guiyu, L., Hodges, H. F. and McKinion, J. M. 1996. Photon flux density versus leaf senescence in determining photosynthetic efficiency and capacity of *Gossypium hirsutum* L. leaves. Environmental and Experimental Botany 36:439-446.

Schubert, A.M., C.R. Benedict, J.D. Berlin, and R.J. Kohel. 1973. Cotton fiber development- Kinetics of cell elongation and secondary wall thickening. Crop Sci. 13:704-709.

Seagull, R. and S. Giavalis. 2004. Pre- and post-anthesis application of exogenous hormones alters fiber production in *Gossypium hirsutum* L. cultivar Maxxa GTO J. of Cotton Sci. 8:105-111.

Smith, C. Wayne. 2003. Registration of TAM 94L-25 and TAM 94J-3 germplasm lines of upland cotton with improved fiber length. Crop Sci. 43:742-743.

Smith, C.W., S. Hague, P.S. Thaxton, E. Hequet, and D. Jones. 2009. Registration of eight extra long staple upland cotton germplasm lines. J. Plant Registration 3:81-85.

Stewart, J.M. 1975. *In-ovulo* embryo culture and seedling development of cotton (*Gossypium hirsutum* L.). Planta. 137:113-117.

Sun, Y., S. Veerabomma, H.A. Abdel-Mageed, M. Fokar, T. Asami, S.Yoshida, and R.D. Allen. 2005. Brassinosteriod regulates fiber development on cultured cotton ovules. Plant Cell Physiol. 46:1384-1391.

Taiz, L. and E. Zeiger. 2006. Plant Physiology. Sinauer and Associates, Sunderland, MA.

Thaker, V.S., S. Saroop, P.P. Vaishnav, and Y.D. Singh. 1986. Role of peroxidase and esterase activities during cotton fiber development. J.Plant Growth Regul. 5:17-27.

Triplett, B. 2000. Cotton ovule culture: A tool for basic biology, biotechnology and cotton improvement. *In Vitro* Cell Dev. Biol. Plant. 36:93-101.

Van't Hof, J. 1998. Production of micronucleoli and onset of cotton fiber growth. Planta. 205:561-566.

Wang, Y., H. Shu, B.Chen, M.E. McGriffen, Jr., W. Zhang, N. Xu, Z. Zhou. 2009. The rate of cellulose increase is highly related to cotton fibre strength and is significantly determined by its genetic background and boll period temperature. J. Plant Growth Regul. 57:203-209.

Xie, W., N.L. Trolinder, and C.H. Haigler. 1993. Cool temperature effects on cotton fiber initiation and elongation clarified using *in vitro* cultures. Crop Sci..33:1258-1264.

Zhao, D. and D.M. Oosterhuis. 2000. Cotton responses to shade at different growth stages: growth, lint yield and fibre quality. Expl. Agric. 36:27-39.

APPENDIX A

Table 20. Summary of weather conditions by week of the 2008 growing season at College Station, TX.

Week ending	Temperature °C			Precipitation		Total Cumul. Degree-
	High	Low	Avg	Current week (mm)	Rainy Days	Base 60F Since April 1
4-May	28	18	23	46	3	434
11-May	26	17	22	64	2	511
18-May	33	22	28	0	0	665
25-May	33	22	28	0	0	819
1-Jun	35	24	30	1	1	1001
8-Jun	35	24	29	0	0	1176
15-Jun	36	23	30	0	0	1358
22-Jun	36	23	30	0	0	1540
29-Jun	35	22	29	7	1	1708
6-Jul	36	23	29	5	3	1883
13-Jul	37	23	30	3	2	2065
20-Jul	37	24	31	2	2	2254
27-Jul	38	24	31	0	0	2450
3-Aug	37	24	31	45	3	2639
10-Aug	34	25	30	68	2	2821
17-Aug	32	24	28	51	5	2975
24-Aug	34	24	29	5	1	3150
31-Aug	34	22	28	0	0	3311
7-Sep	34	23	28	84	2	3472
14-Sep	27	17	22	4	2	3556
21-Sep	31	19	25	0	1	3675
28-Sep	31	15	23	0	0	3773
5-Oct	29	16	23	21	1	3864
12-Oct	27	18	23	23	2	3955
19-Oct	26	12	19	0	1	3997
26-Oct	25	9	17	0	0	4018
2-Nov	26	13	19	8	1	4067
Total				437	35	

Table 21. Summary of weather conditions by week of the 2009 growing season at College Station, TX.

	Temperature °C			Precipitation		Total Cumul. Degree-
Week ending	High	Low	Avg	Current week (mm)	Rainy Days	Base 60F Since April 1
3-May	31	26	26	6	1	406
10-May	32	22	27	21	1	553
17-May	28	16	22	1	1	637
24-May	31	20	26	9	1	763
31-May	33	19	26	0	0	896
7-Jun	36	24	30	0	0	1078
14-Jun	37	24	31	0	0	1274
21-Jun	39	25	32	0	0	1484
28-Jun	38	26	32	0	0	1694
5-Jul	39	26	33	0	0	1911
12-Jul	39	25	32	0	0	2121
19-Jul	37	25	31	53	6	2317
26-Jul	37	26	32	8	3	2520
2-Aug	38	25	32	0	0	2723
9-Aug	38	24	31	0	1	2919
16-Aug	38	25	31	0	0	3115
23-Aug	37	24	30	17	5	3297
30-Aug	34	22	28	0	0	3458
6-Sep	32	23	28	96	4	3612
13-Sep	29	22	26	25	3	3738
20-Sep	28	19	24	59	3	3843
27-Sep	30	20	25	26	3	3962
4-Oct	28	20	24	62	4	4067
11-Oct	26	18	22	37	3	4144
18-Oct	24	12	18	26	2	4179
25-Oct	24	12	18	67	5	4207
1-Nov	26	11	18	0	1	4242
Total				513	47	

VITA

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